INSECTS AND THEIR ALLIES.

BY A. S. PACKARD, JR., M. D.

That branch of the Animal Kingdom known as the ARTICULATA, is so called from having the body composed of rings or segments, like short cylinders, which are placed successively one behind the other. Cuvier selected this term because he saw that the plan of their entire organization, the essential features which separate them from all other animals, lay in the idea of articulation, the apparent joining together of distinct segments along the line of the body. If we observe carefully the body of the Worm, we shall see that it consists of a long cylindrical sac, which at regular intervals is folded in upon itself, thus giving a ringed, annulated or articulated appearance to the body. In the Crustacea (Crabs, Lobsters, etc.) and in the Insects, from the deposition of an earthy salt, called *chitine*, the walls of the body become so hardened, that when the animal is dead and dry, it readily breaks into numerous very perfect rings.

Fig. 1.

Worm-like larva of a Fly, *Thereva?*

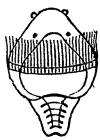
Though this branch contains a far greater number of species than any other of the animal kingdom, their myriad forms can all be reduced to a simple, ideal, typical figure; that of a long slender cylinder divided into numerous segments, as in Fig. 1, representing the larva of a Fly. It is by the unequal development and the various modes of grouping them, as well as the differences in the number of the rings themselves, and also in the changes of form of their appendages, i. e., the feet, jaws, antennæ and wings, that the various forms of Articulates are produced.

In all Articulates the long, tubular, alimentary canal occupies the centre of the body; above it lies the "heart,"

or dorsal vessel, and below, upon the under side, rests the nervous system. The breathing apparatus, or "lungs," in Worms consists of simple filaments, placed on the front of the head; or of gill-like processes, as in the Crustacea, which form simple expansions of the legs; or, as in the Insects, of delicate tubes (*tracheæ*), which ramify throughout the whole interior of the animal, and connect with breathing pores (*stigmata*) in the sides of the body. They do not breathe through the mouth as do the higher animals. The tracheæ and blood-vessels follow closely the same course, so that the aëration of the blood goes on, apparently, over the whole interior of the body, not being confined to a single region, as in the lungs of the vertebrate animals.

Thus it is by observing the general form of the body-walls, and the situation of the different anatomical systems, both in relation to themselves and the walls of the body, or crust, which surrounds and protects the more delicate organs within, that we are able to find satisfactory characters for isolating, in our definitions, the articulates from all other animals.

Fig. 2.



Young Terebella, soon after leaving the egg. A. AGASSIZ.

We shall perceive more clearly the differences between the three classes of articulates, or jointed animals, by examining their young stages, from the time of their exclusion from the egg, until they pass into mature life. A more careful study of this period than we are able to enter upon at present, would show us how much alike the young of all articulates are at first, and how soon they begin to differ, and assume the shape of their class.

Most Worms, after leaving the egg, are at first like some infusoria, being little sac-like animalcules, often ciliated over nearly the entire surface of the infinitesimal

body. Soon this sac-like body grows longer, and contracts at intervals; the intervening parts become unequally enlarged, some segments or rings, formed by the contraction of the body-walls, greatly exceeding in size those next to them; and it thus assumes the appearance of a being, more or less equally ringed, such as in the young Terebella, here figured, where the ciliæ are restricted to a single ring surrounding the body. Gradually the ciliæ disappear and regular locomotive organs, consisting of minute paddles, grow out from the side; feelers (antennæ), jaws, and eyes (simple rudimentary eyes) appear on the few front rings of the body, which are grouped by themselves into a sort of head, though it is difficult in a large proportion of the lower worms, for unskilled observers to distinguish the head from the tail. In the embryo of the Crustacean, such as the Fresh-water Crawfish, as shown by the German naturalist Rathke; and also in the earliest stages of the Insect, the body *at once* assumes a worm-like form, thus beginning its embryonic life from the goal reached by the adult worm.

Thus we see throughout the growth of the worm, no attempt at subdividing the body into regions, each endowed with its peculiar functions; but only a more perfect system of rings, each relatively very equally developed, but all becoming respectively more complicated. For example, in the fresh-water Nais, each ring is plainly distinguished into an upper and under side, and in addition to these a well marked side-area, to which, as in the marine worm, *Nereis*, oar and paddle-like organs are attached; in most other worms eye-spots appear on the front rings, and slender tentacles grow out, and a pair of nerve-knots (*ganglia*) are apportioned to each ring.

Thus, in the Worm the vital force is very equally distrib-

uted to each zoölogical element, or ring of the body; no single part of the body is much honored above the rest, so as to subordinate and hold the other parts in subservience to its peculiar and higher ends in the animal economy.

But when we rise in the scale of articulate life, we see at once the action of a new principle. First in the Crustacean appears a broad distinction between the front and posterior end of the body. The rings are now grouped into two regions, and the hinder division is subordinate in its structure and uses to the forward portion of the body. Hence the nervous power is transferred in some degree towards the head. The organs performing the functions that distinguish animals from plants, such as locomotion and sensation, all reside in the front region; while the vegetative functions, or those concerned in the reproduction and nourishment of the animal produced, are mostly carried on in the hinder region of the body (the abdomen).

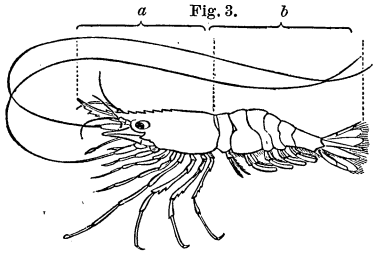


Fig. 3.

Pandalus annulicornis Leach. A Shrimp.
a. cephalothorax; *b*. abdomen.

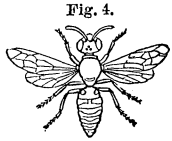
The Crustacean cannot be said to have a true head, in distinction from a thorax bearing the organs of locomotion, but rather a group of rings, to which are appended the organs of sensation and locomotion.

Sometimes the jaws become remarkably like claws; or the legs resemble jaws at the base, but towards their tips become claw-like; gill-like bodies are sometimes attached to the foot-jaws, and thus, as stated by Prof. J. D. Dana, in the introduction to his great work on the Crustacea of the United States Exploring Expedition, the typical Crus-

tacea do not have a distinct head, but rather a "head-thorax" (*cephalo-thorax*).

When we rise a third and last step into the world of Insect forms, we see a completion and final development of the articulate plan which has been but obscurely hinted at in the two lowest classes, the Worms and Crustacea. Here we first meet with a true head, separate in its structure and functions from the thorax, which, in its turn, is clearly distinguishable from the third region of the body, the abdomen, or hind-body. These three regions, as seen in the wasp, are each provided with three distinct sets of organs, each having distinct functions, though all are governed by, and minister to the brain force, now in a great measure gathered up from the posterior rings of the body, and in a more concentrated form (the brain), lodged in the head.

Fig. 4.



Philanthus ventilabris Fabr. A Wood-wasp. From SAY.

Here, then, is a centralization of parts headwards; they are brought as if towards a focus, and that focus the head, which is the meaning of the term "cephalization," proposed by Professor Dana.* *Ring* distinctions have given away to *regional* distinctions. The former characterize the Worm, the latter, the Insect. In other words, the division of the body into three parts, or regions, is in the insect, on the whole, better marked than the division of any one of those parts, except the abdomen, into rings. This is

*In two papers on the Classification of Animals, published in the *American Journal of Science and Arts*, Second Series, vol. xxxv, p. 65, vol. xxxvi, July 1863, and also in his earlier paper on Crustaceans, "the principle of cephalization is shown to be exhibited among animals in the following ways:—

1. By a transfer of members from the *locomotive* to the *cephalic* series.
2. By the anterior of the locomotive organs participating to some extent in cephalic functions.
3. By increased abbreviation, concentration, compactness, and perfection of structure, in the parts and organs of the anterior portion of the body.
4. By increased abbreviation, condensation, and perfection of structure in the posterior, or gastric and caudal portion of the body.
5. By an upward rise in the cephalic end of the nervous system. This rise reaches its extreme limit in Man."

well illustrated in the thorax of the Wasp. In reality the thorax of this insect consists of three rings, with a supernumary one—the first and basal ring of the abdomen—thus forming a compact mass, consisting of four of these rings. But all are so intimately united into an almost spherical, rounded mass, which is due to the unequal size of the parts composing the rings, some being enlarged, and others either diminished in size, or wholly wanting, that it needs the sagacity of a Latreille, or an Audouin, those fathers of Entomology, to detect the actual number of the elemental rings.

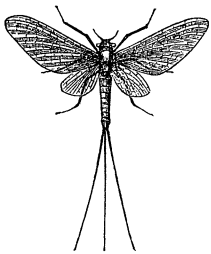
Appended to the head, as the legs to the thorax, are special organs of sight and touch, into which the brain is immediately projected; as the simple and compound eyes, and the antennæ, each with their separate pair of nerves. These are placed in front of the mouth. Behind the mouth, and on each side, are the jaws or mandibles, the maxillæ with their palpi (or touchers), and last of all, and next to the thorax, the labium, or under lip, and its palpi. Before the larva leaves the egg, these four pair of appendages are much alike in form, budding out as simple tubercles, and their relative position and succession are as given above; but during growth they change their position, crowd forward about the mouth-opening, so as to lose nearly all traces of their normal succession, and, in consequence, the labial palpi seem to be more properly placed in advance of the maxillæ, while the mandibles appear, on their part, to be inserted at the base of the head next to the thorax; and it is only by tracing their origin and development, as given in the works of Claparède and Weismann, which we shall farther notice in this journal, that we have been able to understand their normal position.

Insects, as a whole, are much smaller than the Crustacea; for example, compare a Honey bee or Hawk moth with a Lobster or Crab. This diminution of size is due to the greater concentration of parts, and their compression into a much less bulk. Crustacea are mostly inhabitants of the water, while Insects are, in some form, almost exclusively terrestrial. As the Whale exceeds in size the Dog or Lion, or Man himself, so does the Lobster surpass in bulk the Bee, though the latter is a much more highly organized animal, with a more complicated outer crust, a more complex system of nerves, bloodvessels and muscles.

There are various grades of superiority among insects. Rank among men is determined by one's superior intelligence, and less and less likeness to the savage. Thus writers on Ethnology place the European and Australasian at two extremes. On this principle the zoölogist classifies animals by their greater or less resemblance to the lowest types. Thus among Articulates, the Worms are the simplest in form, and in all respects the lowest. The Crustacea are placed next in the natural system, which leaves the Insects topping the series. In classifying the subdivisions of the class of Insects, we observe the same principle. In locating an Insect in what seems to us its true place within its own group, we must follow this rule, i.e., its greater or less resemblance to the typical wormlike form, for the more the body is developed *headwards* the higher is its rank. Among the lowest Insects are the May-flies (*Ephemera*), the Panorpa, or Forceps-tail, and the Spring-tails (*Podura* and *Lepisma*). In these forms the body is slender and wormlike, and the head is many times smaller than the rest of the body. In the Honey bee however, which is the highest among all articulates, the head is but little smaller, and yet very distinct from

the thorax; which again, is but a little smaller than the abdomen. In the Bee, more than in other insects, the rings, or parts of rings remaining after the growth of the animal has been completed, are more equally developed than in the lower insects—no single part attains a monstrous development over the other, as in the May-fly or Dragon-fly. The Bee, of all insects, performs the most varied and complex intellectual acts; in its immense colonies—a rude foreshadowing of human republics—are portioned out to the Queen, the Worker and the Drone, special duties in the insect economy. How varied those duties are, how readily a Worker will perform some acts rarely or never before attempted, and how ready these insects, and their allies, the Ants, are to adapt themselves to new and untried circumstances, all Bee keepers and entomologists are well aware.

Fig. 5.



Ephemera, May Fly.

Let us for a moment look more closely at the tough parchment-like crust of the Insect. We shall then better understand what has been said of its complexity. We find that each ring when examined by itself, consists of an upper (*tergite*), and under (*sternite*), and side-pieces (*pleurite*, consisting of the *epimerum* and *episternum*). These sections of a circle rest on each other, giving the greatest strength and resistance to the whole ring. In the perfect insect the simplest form of the elemental ring is found in the abdomen. The upper and lower arcs are nearly equal in size, and the side-piece is also well mark-

Fig. 6.*

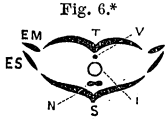


*Fig. 6. Section of an abdominal segment of an hemipter, *Ranatra*. T. tergum; S. sternum; EM. epimerum; ES. episternum; N. nervous system; I. alimentary canal; V. dorsal vessel. L. DUTHIERS.

ed, as seen in the body of the caterpillar. When, however we turn to a thoracic segment, the relative size of the pieces is very unequal, the side-pieces being much larger than the upper or under piece, especially in the Dragon-fly, which is ever on the wing. In the Libellula, the upper part of the ring is greatly reduced in size, and the larger part of the ring consists of the side-pieces. As a rule, however, the under piece (*sternum*) is very small, the dorsal or upper-piece (*tergum*) is well developed, while the side-pieces are increased in a still greater ratio, as seen in the Wasp, which walks and also flies with ease. The side, or limb-bearing part of the ring, is generally largest in the running insects, as in the Beetles, of which *Carabus*, the Ground-beetle, is a type. On the other hand the dorsal (or *tergal* piece, the more technical name, since the word dorsal is more appropriate in speaking of the vertebrates, or animals with a back bone) part of the ring is quite small in the Dragon-fly and its allies. In these insects, which scarcely ever walk, merely using their legs in clinging to plants when resting from their long sustained flights, the side-pieces are disproportionately enlarged over the other parts of the ring, for the purpose of affording broad attachments to the muscles of flight.

To the side pieces all the appendages, such as the legs and wings, are attached. In order that the legs may move freely on the body, and thus give play to hundreds of minute muscles within the legs, these side pieces are subdivided into several smaller sections. Were this not so, and the crust forming the exterior of the insect unbroken, thus forming a continuous series of cylinders, we should have the poor victims of this stern law of morphology enclosed in jackets of the straightest sort!

Whence comes, then, all the grace and perfect freedom of action seen in the vivacious motions of the Ichneumon fly and Butterfly? It lies in the fact that the whole outer crust is subdivided into portions which are finely hinged together by a tough membrane, forming points of attachment to thousands of little muscular fibres within, and thus giving the otherwise rigid crust a surprising degree of flexibility.

The three pair of legs are inserted at the lower edge of the side-piece (episternum, Fig, 6, ES), as seen in the figure, and the wings grow out between the upper side piece, (Fig. 6, EM) and the tergum (Fig. 6, T). The body of all known insects consists normally of twenty of these cylindrical rings, each of which is theoretically subdivided in the manner we have shown; but towards each extremity of the body, as in the rings composing the head and tail, but a part of the ring is developed, since the remaining portions have, during the development of the animal, either while still in the egg, or during its growth afterwards, become absorbed, and have consequently disappeared. In the head of all insects there are, as a rule, seven such rings, in the thorax three, and in the hind body, or abdomen, at least ten, and perhaps eleven, elemental segments. Counting, in addition to the great number of pieces which compose the trunk, the numerous joints of the legs, and those of the antennæ, which approach in the Cockroach to nearly a hundred in number, we can form some idea of the exceeding complexity of the insectean crust. Thus descriptive entomology has to take account of several hundred distinct parts, which by their relative size and position, produce the immense range of variation existing in nearly half a million species which are estimated to be scattered over the face of the earth,

besides those entombed in its crust, as fossils, which can never be numbered.

Thus the idea of articulation, upon which Cuvier founded this branch of the animal kingdom, which begins so simply in the worm and grows far more complex in the crab and its allies, is, in the insect, carried out with a bewildering richness and profusion of detail. It is like comparing a savage's "dug out" to the "Great Eastern" steamship, or the rude wigwam of an Indian to the Cathedral of Milan.

The German Naturalist Oken, who in his writings has so often anticipated the results of subsequent laborious inquiries, said in his aphoristic style when discoursing of insects: "Every fly creeps as a worm out of the egg; then by changing into the pupa, it becomes a crab, and, lastly, a perfect fly." The motions of these worms and crabs to which he aptly compares the two stages of the young fly, will show a farther analogy, though to many it may seem fanciful, between these forms of jointed animals. Worms wriggle along as they move. Now wriggling is one of the lowest forms of locomotion. The waddling of geese partakes of the same nature. In worms, the many rings of the body, so similar to each other in form and size, move on themselves, and then move all together, and thus the creature progresses. In pupæ the abdomen moves upon the forward part of the body; the insect *jerks* about by the motive power residing in the abdomen. Here is indeed a localization of the power of motion, and something is gained in the rising scale. Now the Crustacea, or crabs and their allies, all move by jerking. Watch the microscopic Cypris or larger Cyclops, in its swift circumnavigation of a drop of water. It moves both by its thoracic legs, and by the locomotive

power of its abdomen or hind-body, as it swims through its little "world of waters" by jerks. So also the Amphipod, a crab-like being, higher in the scale than the water flea, darts from weed to weed in the clear cool waters of tidal pools, by most gracefully jerking its abdominal rings. So also the clumsy crab clambers cautiously obliquely backwards over the pebbles by a jerking sort of gait; and the lobster carelessly bends its tail beneath its breast, and like a flash, lands softly a fathom away, in its course leaping the Laminaria swaying to and fro in the ebbing tide.

Compare with these stiff and clumsy motions, the flight of a swallow-tailed Butterfly, as it emulates all the motions of an eagle in its majestic flight over forests and through sequestered glades. The lowest of butterflies, the small dun colored Hesperiadæ, or Skippers, *jerk* as they fly. Or compare again the swift, vivacious, inquisitive motions of an Ichneumon fly, just as it has alighted upon a leaf. See the intensity of life in every movement of its open, restless wings; the head turning this way and that, with the vibrating feelers and threadlike waving antennæ, prompted by the nervous energy within; its arching abdomen directing each incessant and swift darting movement of its ovipositor, while running from leaf to leaf in its anxious search for some unlucky caterpillar in which to lay its eggs. In this tiny insect is a specialization of motion in every limb and section of its body, to which no lower articulate can attain.

Thus we see a certain degree of correspondence between the various modes of locomotion of the different groups of animals and their position in nature.